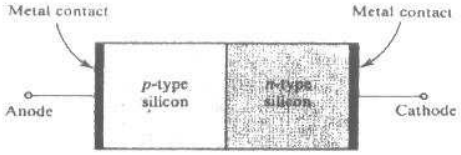
1. For the *pn* junction diode shown below, assuming that the *p* region is more heavily doped than the *n* region;

   (a) When the *pn* junction is forward-biased, plot the minority-carrier distribution and the majority-carrier diffusion current density. (5%)

   (b) When the *pn* junction is reverse-biased, plot the minority-carrier distribution and the majority-carrier diffusion current density. (5%)



2. (a) Explain "Ebers-Moll Model" for the BJT. Please draw the model. (3%)

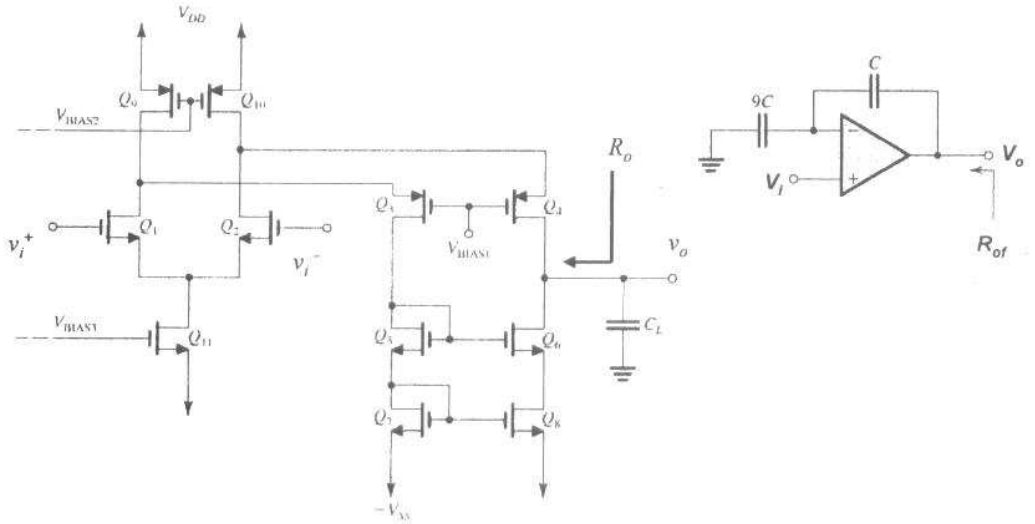
   (b) Explain what "Saturation" means in BJT's operation. (2%)

   (c) Plot the high-frequency hybrid-π model of an npn BJT transistor. Label every component. (3%)

3. Consider a design of the cascode op amp shown below for which I = 125 μA and I_B = 150 μA. Assume that all transistors are operated at $|V_{ov}|$ = 0.15 V and that for all devices, the Early voltage $|V_A|$ = 12 V. $V_{DD} = V_{SS}$ = 3 V. (20%)

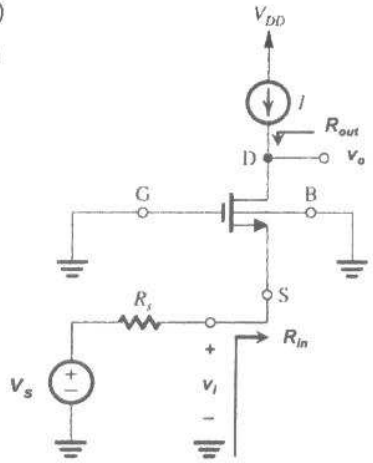
   (a) Calculate the overall transconductance G_m, output resistance R_o, and $A_v = v_o/(v_i^+ - v_i^-)$.

   (b) If the op amp is connected in the feedback configuration shown below, find the voltage gain and the output resistance of the closed-loop amplifier.

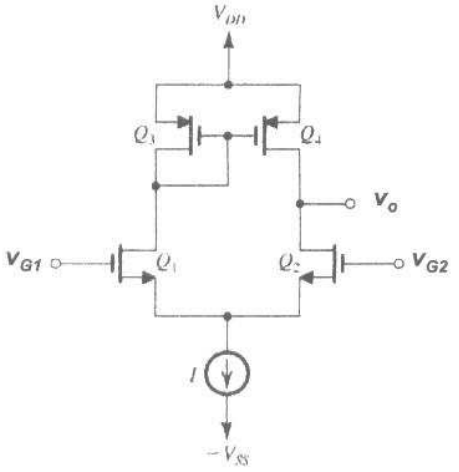


4. Use CMOS logic circuit to realize a three-input even-parity checker. Specifically, the output Y is to be low when an even number of the inputs A, B, and C are high. Please sketch your design. (12%)

5. For the NMOS amplifier shown, (20%)
   (a) sketch the equivalent circuit for small signal analysis, and derive the expressions for
   (b) the input resistance R_{in},
   (c) the voltage gains v_o / v_s,
   (d) the output resistance R_{out}, and
   (e) the 3-dB frequency f_H.



6. For the active–loaded MOS differential pair, (15%)
   derive the expressions for
   (a) the output resistance R_o,
   (b) the differential gain A_d,
   (c) the common-mode gain A_{cm}, and
   (d) the common-mode-rejection-ratio (*CMRR*).



7. For the feedback amplifier, the op amp is characterized by an open-loop voltage gain μ. (15%)
   (a) Determine the feedback type of the amplifier, and derive the expressions for
   (b) the gain-with-feedback $A_f \equiv i_o / v_s$,
   (c) the input resistance R_{in}, and
   (d) the input resistance R_{out}.